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THE LATE BLIGHT OF CELERY

By STANLEY S. ROGERS

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Field of banked celery.

THE LATE BLIGHT OF CELERY

By STANLEY S. ROGERS

SUMMARY.

1[1] "In the peat lands of Orange County, located between Santa Ana and the Coast, in the vicinity of Smeltzer, a very large celery growing industry has developed, the crop being grown particularly for shipment during the winter after the eastern celery has had its season. During the summer of 1907 nearly six thousand acres of celery were planted in this district. Great losses in the crop were experienced in the winter of 1908 from a fungus disease causing a blight of the leaves of the celery plant and heavy decay during shipment. The fungus responsible for this disease is *Septoria petroselini* var. *apii*. These losses were estimated as causing a shrinkage of 1950 car loads in shipment, and had a most disastrous effect upon the quality of the celery on arrival in the eastern markets and the financial returns from the crop. The whole money loss for the season caused by this fungus disease was conservatively estimated at $550,000.00."

2. The celery blight is one of the many fungus diseases which may be controlled by spraying with Bordeaux mixture.

3. While a great deal of spraying was done in the season of 1908, the results were not uniformly satisfactory; failures in controlling the disease being chargeable to many different causes.

4. The efforts of the Experiment Station have been directed towards working out the details involved in the control of this disease and in demonstrating the most successful methods. Such points as when and how often to spray; what strength of Bordeaux to use; how to prepare the spray mixture economically, accurately and rapidly; how to apply it efficiently; the agencies involved in the spread of the fungus from plant to plant and from field to field; the relation between the weather and the frequency of spraying.

5. Based on the results of the investigation the following spraying scheme is recommended:

[1] See California Station Bulletin No. 203, page 41.

(a) The formula for Bordeaux should be 5 pounds of blue stone, 6 pounds of stone lime and 50 gallons of water. When the plants are small 30 to 40 gallons of Bordeaux per acre is sufficient; but the amount should be increased at each application so that when the plants are 15 or more inches high the spray is put on at the rate of not less than 100 gallons per acre.

(b) Spray seed beds at least twice, especially if grown on soil which produced blighted celery the preceding year.

(c) After plants are transplanted into the field spraying should begin when the first blight is noticed. In any event, the first spraying should be given not later than six weeks after transplanting and one application a month should be given until the seasonal rain or heavy fog comes.

(d) After the rains have set in spray every two weeks if possible until the crop is harvested.

(e) Where the plants are over 15 inches tall, they should be gone over twice at each spraying, the machine moving in the opposite direction the second time.

(f) Upon the carefulness and thoroughness of the spraying is dependent to a large extent the successful control of the blight.

6. Demonstration plots sprayed by the writer according to the above scheme came through the season in first class shape and were almost entirely free from blight at harvest time.

FOREWORD.

The object of this bulletin is to give an outline of the history and a description of the appearance, together with an account of the cause and control of the most serious disease with which the celery growers of this State have to contend. This publication covers the work which has been done by the University of California Experiment Station on this disease during the past four years, but dwells chiefly with the observations and results of the experiments carried on in the celery fields in Orange County during the season of 1909 and spring of 1910. Before beginning an account of this work done upon the blight, a few pages will be devoted to a consideration of the celery plant and the methods of growing and marketing the crop.

METHODS OF GROWING AND HANDLING CELERY.

Of the early history of the celery plant very little is known, except that it has been found growing wild in the marshes in Europe and England. The flavor of the wild celery is very disagreeable and the

plant is unfit for food. By careful selection and improvement in its culture it has been changed until it is now considered one of the most important, refreshing and healthful vegetables grown. On account of a steady growth in popularity and increase in consumption, celery culture has become a very important industry. Especially in California where the climatic and soil conditions are so favorable, the importance of this crop has grown rapidly until in Orange County alone, during the last season, over 3,000 acres of celery were grown.

Soils Adapted to Celery Growing.—Celery is very poorly adapted to worn-out or impoverished land. To grow a profitable celery crop, the soil should be well supplied with the essential elements of plant food. This crop grows well on nearly all types of soil but peat land is probably the best, although the writer has seen some excellent results on both adobe and light sandy loam. As a rule the plants are slow in starting their growth on the heavier soils, but the yield is generally larger and the celery is of better flavor than that grown on lighter land.

Varieties.—Several varieties of celery have been tested in this State, but the Golden Self-Blanching is most popular and profitable.

The Seed Bed.—It is very essential that the ground to be used for growing the young plants should be put into as fine a condition as possible. The celery seed is so small (one ounce is said to contain between 60,000 and 70,000 seed) that unless the ground is well pulverized it is difficult to get a good stand. It is generally estimated that enough plants may be grown on one acre of seed bed to plant twenty acres in the field. In order to produce healthy, vigorous plants, heavy watering is the rule at first, but as soon as the plants have commenced to grow the quantity of water is reduced, and should never be allowed to stand on the surface of the bed. In order to accomplish this the land must be well drained. In the southern part of the State the seed is usually sown in March.

Preparation of the Fields for the Seedling Plants.—While it is not, perhaps, as important to get the land in the field in as fine condition as for the seed bed, yet the best results cannot be obtained unless the soil has been put into very fine condition, consequently a great deal of care should be used in working and reworking the soil previous to planting.

Irrigation.—Although not nearly as much water is required for the plants in the field as in the seed bed, celery plants cannot stand drought at any stage of their growth, consequently a well controlled

irrigation system is imperative, except where the water table is close to the surface. This, however, is the exception in Orange County.

Drainage.—Good, thorough drainage is just as important as irrigation. Although the celery crop can easily be ruined if the water supply is inadequate, too much water is just as objectionable. If water is allowed to stand in the field even for a short time, the plants will suffer seriously. As most of the celery land is low and the ordinary drainage is poor, an extended system of tile drainage has been made in nearly all the celery fields of Orange County in order to prevent losses from standing water. There are several different kinds of tile in use, the round tile being most popular.

Transplanting.—When the plants are large enough to be transplanted, they are pulled from the seed beds, placed in tin pans and hauled to the field, where they are planted six inches apart in the furrows three and one-half feet apart. The depth of the furrows in which the plants are set is somewhat varied, depending on the soil, moisture, and the size of the plants. The average depth is from three to five inches.

Cultivating.—After the plants have been set out into the field the cultivator should be used often in order that all weeds may be killed while germinating and to keep the moisture in the ground for utilization of the crop. The field should be cultivated thoroughly throughout the entire season, especially if weed seeds are abundant in the soil or the amount of moisture is less than desired.

Crowding.—After the plants have been set in the field for about three weeks or a month and have recovered from the transplanting, the field is "crowded." This operation consists in moving the earth away from the young plants so that they will have more air around them and to kill what weeds have grown so close to the plants that it is impossible to reach them with the cultivator. This helps to conserve the moisture as well.

Rolling.—The earth between the rows of plants is left in a ridge after the plants have been "crowded." A large wooden roller which extends across several rows is now used to flatten down these ridges and pack the soil more firmly. The roller is used only when the plants are small, otherwise they would be injured by being crushed. When the plants have grown sufficiently to be injured by this rolling of the middles, the ridges are smoothed down by the cultivator.

Splitting.—When the plants are twelve to fifteen inches tall, earth from between the rows is drawn up to them. This is termed "splitting." This should be done carefully, for, if the earth is put too close

Fig. 1.—Pulling young celery plants from seed bed.

Fig. 2.—Transplanting celery into the fields.

or too high up on the plants, they will become tender and weak, especially if the weather is hot. The object of "splitting" is to gradually encourage the plants to grow tall and straight instead of spreading out. This operation is repeated twice during the season, the first time when the plants are fourteen to sixteen inches tall and the second time just before banking. This last "splitting" also aids blanching.

Banking.—All the celery grown in California is banked with earth for blanching. Blanching is done when the celery is reaching its maturity and is nearly ready for shipment. This is the last field operation before the crop is cut. When the celery is banked for the first time the earth is not drawn very high on the plants, but each time the field is banked the soil is drawn higher so as to firmly hold the leaves together and in an upright position. If celery that has been banked for the last time is not harvested shortly, it will soon become "punky." The length of time that it can safely be left in the bank depends upon the character of the soil, the weather conditions, and upon the condition of the plants themselves. Celery on sandy soil will keep much longer in the bank than on adobe or peat soil. If the celery has not matured or if the weather is hot or moist its keeping quality will be injured. Holding too long in the bank will result in a wilted and "punky" product.

Fig. 3.—Harvesting celery.

Cutting.—When the celery is ready to harvest a cutting machine is used which cuts off the plants just below the crown, leaving a few roots attached. The plants are then lifted and shaken free from soil, trimmed and thrown in piles by laborers, who are usually Japanese. Another gang of men then place the plants in crates, marking on each crate the number of dozen it contains. More men follow, nail the crates securely, load them on wagons which transport them to the railroad siding, where they are ready for shipment and distribution to the various markets in the United States and Canada.

Marketing.—A very efficient system has been developed by which this crop is sold. There are in this State a number of commission men and companies which sell the crop for the growers, but the largest is the California Vegetable Union. This large organization has its representatives in many of the leading markets and by the use of telephones and telegrams market conditions are known each day and the celery is shipped to the points of greatest demand.

THE LATE BLIGHT OF CELERY.

Septoria petroselini Desm., var. *apii* Br. and Cav.

History and Distribution.—As before stated, this disease is by far the worst one with which the celery growers in this State have to contend. A comparatively small amount of literature is available which treats of its history and introduction into the United States. The earliest reference to this disease which the writer has been able to find was in 1890. In that year Briosi and Cavara collected a few specimens at Pavia, Italy.[2] The first reference to the late blight in the United States is probably in the year 1891. At that time it was noted in Massachusetts by Humphrey.[3] In New Jersey by Halsted.[4] In Delaware by Chester.[5] In a few of the bulletins issued by the different eastern State Experiment Stations from time to time some little attention is paid to late blight, but in a number no mention is given. A bulletin issued by the New York Experiment Station in 1893 makes the following statement: "So far as could be determined most of the damage from the celery leaf spot in 1892 in Central and Western New York was due to this *Septoria*." From these States it gradually spread west, until in the fall of 1897 the late blight began to be a serious menace to the celery industry in California.

Introduction into California.—During the fall of 1897 the late blight began to be serious in this State. Its presence was noticed in a few of the fields during the two preceding years, but it did not occur commonly enough to be of commercial importance. A clipping from a letter written by a celery grower in Orange County in December, 1907, will illustrate the loss caused by this disease in this year: "The celery acreage this year was about 5,000 acres, and during October our celery was seriously affected, especially the early." Another from the same vicinity, dated February, 1909, reads: "I have grown celery for the last two years and both years the blight affected it badly."

[2] Funghi Parisitti Facicola, VI, No. 144.

[3] Annual Report, 1891, Mass. Agr. Exp. Sta., p. 28.

[4] Annual Report, 1891, New Jersey Agr. Exp. Sta., pp. 255 and 256.

[5] Bulletin from the Torrey Botanical Club for 1891, p. 272.

After its introduction into Orange County the blight spread pretty generally over the entire State. A letter from Santa Paula, dated June, 1909, refers to blight which was probably *Septoria,* that was troublesome the preceding year. In the winter of the same year the writer made a trip into the San Joaquin and Sacramento Counties, in both of which the late blight was found. This disease has also been found on celery grown in Los Angeles, San Bernardino and Riverside Counties.

A Description of the Appearance of the Fungus.—The blight first affects the lower outside leaves, where it is seen in small, brown spots, which later turn black. These spots often form in clusters, but where the leaves are badly affected the clusters cover the entire leaf surface and these leaves soon fail to perform their natural function and die.

Fig. 4*a*.—Healthy celery plant.

In Orange County the spots can generally be seen more plainly on the under side of the leaves, while in the fields in the vicinity of Stockton, which is situated in the San Joaquin Valley, the fungus appears on the upper side first. The difference is due, no doubt, to the heavy fogs so common at Stockton, which condense on the upper surface of the leaves. Such tiny drops of water present just the right conditions for the germination of the spores and consequent infection of the

Fig. 4*b*.—Celery plant affected with late blight.

Fig. 5.—Celery leaf affected with late blight.

leaves. In many cases, however, the blight does not confine its ravages to the leaves but attacks the stalks also. Here again it is seen in small black spots, often in clusters at first, but later converging and covering the greater part of the stalk. When the plants are thus infected the prospect for ever producing a marketable product is very poor, for the stalks soon turn brown, soften, and finally shrivel up.

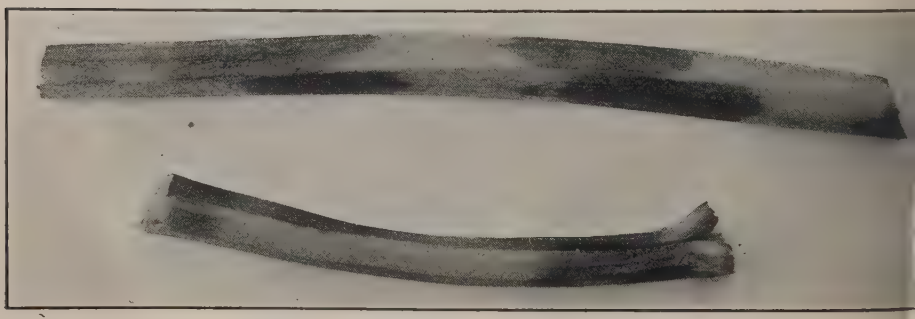

Fig. 6.—Celery stalks affected with late blight.

Shortly after the appearance of the characteristic blight spots upon the leaves and stems described above, there can be seen small, black pustules or pycnidia in the center of the dead areas. With age the pycnidia may reach the margin of the infected area. The small pycnidia, which are less than ¼ mm in diameter, are the fruiting bodies of the fungus. The pustules at maturity contain long, cylindrical, straight or slightly curved, several septate spores. These microscopic spores measure from 20 to 49 μ (μ equals 1/25,000 part of an inch) in length by 1 to 1½ μ in width, and are the means by which

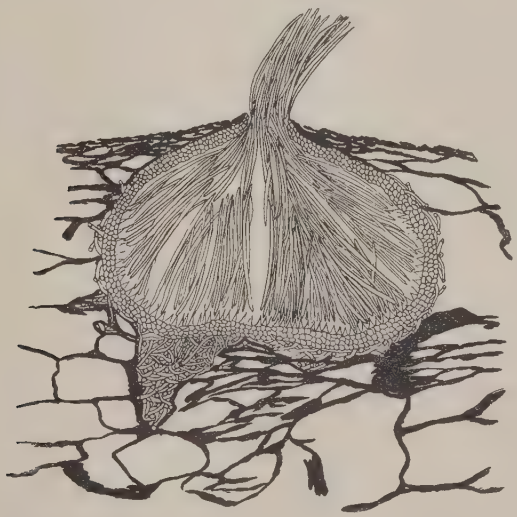

Fig. 7.—Pycnidium showing spores oozing through the ostiole. (Enlarged 320 times.)
Drawing by C. N. Jensen.

the fungus is disseminated upon the same or to other plants. (See fig. 7, which indicates spores oozing from a mature pycnidium.) In a general way the function of these spores is the same as that of the seeds of higher plants. The pycnidium developes immediately underneath the epidermis. Its wall is from two to four cells in thickness and is brown in color. The mouth or ostiolum is round and slightly elevated, and it is through this opening that the spores ooze out when the pycnidium absorbs moisture in foggy or rainy weather.

According to Klebahn (Zeit. fur Pflanzenkrankheiten, January, 1910, p. 8) the mycelium spreads itself into the inter-cellular spaces.

My observations point to the same conclusion, as microscopic leaf and stem sections show the mycelium thus in the tissue. The fungus does not penetrate into the deeper lying tissues but is rather limited to the cells nearer the epidermis and a short distance below.

Means of Dissemination.—As will be seen by the above description, the spores are unable to leave the spore case or pycnidium until moisture conditions are favorable. This accounts for the appearance of the late blight after a heavy fog or rain. Some of the agencies by which the spores are spread are: Moisture, wind, insects, men, tools, horses, etc. But my observations lead me to conclude that irrigating water when run through the furrows in which the plants are set is one of the principal agents in the spread of this fungus. The fields which show the greatest amount of blight previous to the rains have, in nearly every case, been watered as above described; while in those fields which have been watered by running furrows between the rows of plants there is practically no blight, except in the places where the water has run over into the celery rows. The appearance of the blight at such places would seem to strengthen my conclusions. After gaining a foothold in the field the disease spreads very rapidly, especially if the weather is warm and moist, and in a few days a large acreage is destroyed. The blight almost invariably makes its first appearance in the low, wet, poorly drained spots and from these soon spreads to other parts of the field.

SYNOPSIS OF THE WORK IN ORANGE COUNTY.

In Orange County celery has suffered from late blight much more seriously than in any other section of the State. This is not surprising in view of the fact that this County produces the bulk of the celery grown in the State. In fact, celery culture first assumed commercial importance in Orange County and there certain fields have been devoted to celery longer than anywhere else in the State.

Many of the growers have, therefore, joined in the building up of a large and well organized association which controls the sale of the bulk of the crop. When the blight suddenly became serious these men were impressed with the importance of taking immediate steps for the control of this damaging disease. Upon receipt of an urgent letter from the interested parties asking for assistance, a representative from the Experiment Station visited the fields and investigated the situation. The season had advanced so far, however, that it was useless to start any experiments in spraying at that time. Some spraying had already been done by a few of the growers, but as no definite plan had been followed, the results were not very satisfactory, with the single

exception, perhaps, of that done on the Golden West Celery and Produce Company's ranch. The spraying here was carefully done throughout the entire season and the manager, writing on February 25, 1908, states: "I am sorry to say that the celery crop has been completely wiped out, with the exception of that on our ranch. * * * Pleased to state that our celery not only looks well at the time of shipment, but it carries to destination in marketable condition, according to the reports from our eastern agents." The results from the spraying done on this ranch were so encouraging that on March 27th, 1908, a meeting of the members of the Association was held to arrive at some definite plan of campaign and a request was made that a representative from the Experiment Station address the meeting. At this meeting it was decided to spray the celery fields the following year with Bordeaux mixture and the work was to be carried on under the direction of Professor H. J. Ramsey.

From this time on spraying the celery fields became a live problem with the growers. Some few men even sprayed their seed beds as soon as the plants were large enough. In this season the blight first appeared on July 24th. During the summer spraying was done in many of the fields and very little blight appeared until the rains began in the fall. This was as favorable a year for the growth of the late blight as the preceding one had been, but not nearly as large a loss was sustained. This was due to the fact that more of the growers were spraying and they were spraying more thoroughly and persistently. A large per cent of the growers who did no spraying or who sprayed very carelessly, or spasmodically, lost heavily. In general, this resulted in a vast difference in favor of the sprayed over the unsprayed fields. It was, therefore, decided that in order to carry on the work more systematically and in detail it was advisable to secure a man from the Experiment Station who could devote his entire time to a careful supervision of the work. Consequently, on August 1st, 1909, the writer proceeded to Smeltzer, which is in the heart of the celery section, and remained there throughout the season.

EXPERIMENTS AT SMELTZER.

The work at Smeltzer from August 1st, 1909, to January, 1910, was conducted along the following lines: (1) General field observations. (2) The collection of detailed data from fifty-four representative fields. (3) Experiments conducted in the field of carefully measured and prepared plots.

(1) *General Field Observations.*—General field observations were made as often as possible, the object being to get a comprehensive idea

of the extent and effect of this disease on the industry as a whole. It was, of course, impossible to examine every field of the entire three thousand acres planted, but an effort was made to secure data on fields which represented as many of the different varying conditions of soil, drainage, management, etc., as was possible in the time at my disposal. Brief chronological notes on the condition of the 1909 crop follow:

August 17: The celery around Smeltzer is in fairly good condition, although large numbers of yellow plants are in evidence, especially in those fields planted late in the season. Only two or three slight cases of late blight have been noticed. With the exception of one field, no spraying has been done this season.

August 26: The crop in general has made a decided growth since last reported upon and many of the fields that were yellow have become much greener and in better condition. The late blight has increased to some extent but in no instance has the damage been heavy as yet. The damage is not confined to any one section, but is scattered throughout the entire celery producing area.

September 7: The late blight has increased rapidly and has gained quite a foothold in some of the fields, while a large proportion of them show scattering diseased plants which act as centers of infection. As yet, however, no plants have been noted as killed outright. Only a very few growers have commenced to spray. While a cursory survey might lead one to believe that the crop as a whole is in a better condition than last week, a careful examination shows that some of the fields are still yellow, and especially is this the case where the crop is growing on ground that was used for seed bed earlier in the season.

September 18: During the past week there have been some very hot, dry days and much of the older celery, especially that which was planted on heavy soil or on land that was used for seed bed purposes, has been badly sunburned. The lower outer leaves are affected the worst. Much of the late blight has been killed by hot, dry winds. Many of the growers are now spraying but, as a rule, they are either not using enough Bordeaux or are not mixing it properly.

October 9: During the past week one-fourth of an inch of rain has fallen, and this has been favorable for the spread of the fungus. Alarmed by the increase of the disease, attempts at spraying are being made on nearly all of the ranches.

October 15: At this date the blight is spreading rapidly and has been found in many previously healthy fields. One field in particular, which has been quite free from blight up to the last week and has not been sprayed, is now very badly infected.

October 22: Unusually thick, foggy weather during the past few

days has greatly favored the spread of the blight. The larger, earlier planted celery is the worst affected. Fields that have been sprayed carelessly or not at all are in much worse condition than those that were cared for. There is, however, a little blight even in the fields that were well sprayed.

November 3: The situation is now going from bad to worse each week, but the fields that have been thoroughly and properly sprayed are, with very few exceptions, in first class condition.

December 7: Since the last field observations were taken three and one-fourth inches of rain have fallen, which has stimulated the growth of the plants. In the fields which were used for seed beds early in the season the plants are making very slow growth. The blight has been increasing very rapidly since the rain, and some of the fields are in a serious condition. On account of the heavy, washing rains, there are many fields in which the foliage shows no spray. This is strikingly apparent where improperly mixed Bordeaux was used. Wherever the Bordeaux was properly mixed and applied, it remained on the leaves through the drenching rains. In the fields that have not been sprayed the blight is much worse than in those that have.

December 14: During the past week the rainfall has been over two and one-half inches, lasting for three days, and as nearly all the spray has been washed off the plants, the late blight has increased very rapidly. Again it is noted that with no exception the fields that have been sprayed poorly or not at all are nearly ruined by the late blight. In parts of many fields the water has stood around the plants to a depth of two to six inches for several days. In these low places the damage is much more severe. The weather has been foggy ever since the rains stopped, which has made the conditions ideal for the growth of the fungus. The growers are now spraying the fields as often as possible.

January 5: As before stated, the late blight can be found in nearly every field and there is still a very marked difference between those which were sprayed thoroughly and those which were not. In these latter fields the late blight has practically ruined the crop. At this time it requires no expert to realize, after a glance through the fields, that the control of this disease depends upon a regular, systematic and intelligent application of Bordeaux mixture.

(2) *Detailed Observations on Fifty-Four Fields.*—A detailed record was kept of the above number of fields, paying especial attention to the dates of plowing, irrigating, transplanting into the main field, spraying in the seed bed, growth and condition of the plants, spraying

in the fields, presence of early blight, and the date the late blight appeared. It is impracticable here to present all of this data in detail, but the general conclusions will be of considerable interest.

The time and depth of plowing had no effect upon the quantity or the date that the late blight appeared in the fields. Irrigation is the one field operation which bears a close relation to the abundance or scarcity of the late blight. The use of irrigation water in too large quantities so that there is standing water around the plants makes one of the most favorable conditions for the development of the late blight. In Orange County there are two systems of irrigation in use: Sub-irrigation through tile, and ordinary surface irrigation in furrows. In the fields that were sub-irrigated the late blight was very much less (up to the time of the rains) than in those which were irrigated the latter way. Some of the fields were irrigated by running furrows made between the rows of plants, while many others were irrigated by running the water down the rows of celery. As has been before stated, this method is a very unwise one to follow. Good drainage is fully as important as skillful irrigation, for the diseased plants are invariably found first and worst in the poorly drained spots. This is particularly noticeable this season.

No very striking advantage was found this year in spraying the plants in the seed beds, although this practice is strongly advocated as the expense and labor involved is very small in comparison with the results that may be accomplished some years. Especially is this true if the seed bed is on land that grew diseased plants the previous season.

A record was kept of the dates upon which each of the fields we sprayed, and the results bring out a very important fact and are very encouraging. A few of the growers began spraying their fields about the first of September, and by the latter part of the month many of the fields had been gone over once. Nearly all the growers who had sprayed at all had begun operations by the middle of October, while some of the earliest planted fields had by that time been sprayed twice. The general aim was to spray the fields every two or three weeks during the entire season, but on account of the regular routine of ranch work it was not always possible to do so. After the winter rains began it was often impossible to get into the fields as soon as desirable.

The first late blight in the 1909-10 crop seen by the writer was found on August 17th. From this time on the late blight increased, but not until the rains came did it do much damage. The earlier planted larger celery was the first to become infected, and also that which was not sprayed or sprayed carelessly.

(3) *Experiment Field.*—The object of the plot experiments was to determine, if possible, the best time or times to spray in order to control the late blight. This field contained one acre of land and was situated at Smeltzer. The soil was a heavy loam and was in excellent condition, sub-irrigated and drained. This field has been planted continuously to celery for the past fourteen years. It was plowed on May first, irrigated on June 1st, and the celery plants were set on August 1st. As the work of spraying could be carried on much more satisfactorily on small areas, this tract of land was sub-divided into fifty plots, each containing an area of one fiftieth of an acre, so that each consisted of six rows of celery forty-one and four-tenths feet in length. Each plot was large enough to secure reliable results and small enough so that the work could be done thoroughly and on time.

Of course it will be understood that the spraying with Bordeaux mixture for any fungus disease has for its object the prevention of the disease rather than its cure. It is well known that the spores of the fungus cannot germinate and infect the leaf but will be killed if they come in contact with copper sulphate or blue stone. A solution of blue stone alone will kill the leaves, hence the lime is added to prevent this. It will be seen, therefore, that the disease will be prevented only to the extent to which the Bordeaux covers all the surface of the leaves and stalks. Hence the necessity for thorough work. If new leaves grow out, these in turn must be covered with spray and, should a drenching rain wash the Bordeaux off, it is necessary to spray again and as soon as possible.

The spraying of these experimental plots was carried out according to the schedule given below:

Plot Number.	Dates of Spraying.
1	9/15; 10/15; 11/15; 12/15.
2	9/15; 10/1; 10/15; 11/1; 11/15; 12/1; 12/15; 1/1.
3	9/15; 11/15.
4	9/15; 11/1; 11/15; 1/1.
5	9/15; 12/15.
6	9/15; 12/1; 12/15.
7	9/15.
8	9/15.
9	9/15;10/15.
10	9/15; 11/15.
11	9/15; 12/15.
12	9/15.
13	9/15.
14	Spray when necessary; 10/1; 11/1; 12/15; 1/1.
15	Check; left unsprayed.

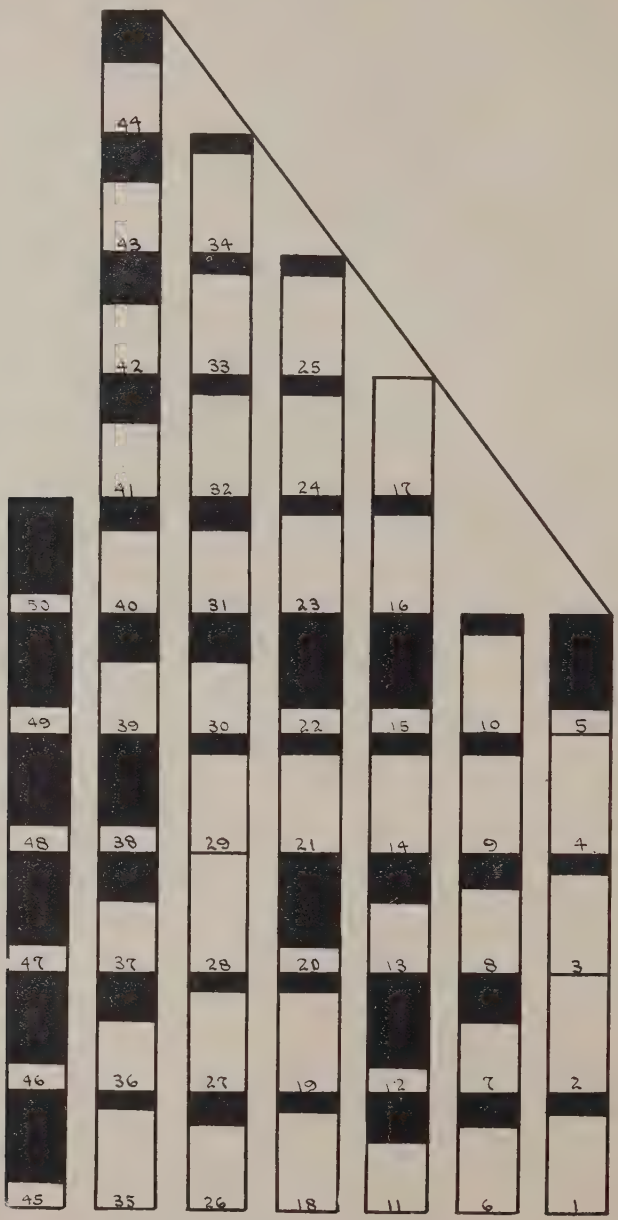

Fig. 8.—Plan of the experiment field. The proportion of black in each plot indicates the amount of blight.

16	10/1; 11/1; 12/; 1/1.
17	10/1; 10/15; 11/1; 11/15; 12/1; 12/15; 1/1.
18	10/1; 12/1.
19	10/; 10/15; 12/1; 12/15.
20	10/1; 1/1.
21	10/1; 10/15; 1/1.
22	10/1.
23	10/1; 10/15.
24	10/1; 11/1.
25	10/1; 12/1.
26	10/1.
27	Spray when necessary; 10/1; 11/1; 12/15; 1/1.
28	11/1; 11/15; 12/1; 12/15; 1/1.
29	11/1; 12/1; 1/1.
30	Check; left unsprayed.
31	11/1; 1/1.
32	11/1; 11/15; 1/1.
33	11/1.
34	11/1; 11/15.
35	11/1; 12/1.
36	11/1.
37	Spray when necessary; 10/1; 11/1; 12/15; 1/1.
38	Check; left unsprayed.
39	12/1; 1/1.
40	12/1; 12/15; 1/1.
41	12/1.
42	12/1; 12/15.
43	12/1; 1/1.
44	12/1.
45	Spray when necessary; 12/1; 12/15; 1/1.
46	Check; left unsprayed.
47	1/1.
48	1/1.
49	Check; left unsprayed.
50	Check; left unsprayed.

Spraying was begun on September 16th and at this time there was no blight on any of the plots.

On October 1st the plots that were sprayed on September 16th had pushed out so many new leaves that it at once became apparent that if celery was to be sprayed for the blight in an ideal way, it would of necessity be an almost continuous performance. But spraying costs money and the question which at once assumed paramount importance was: Just how much time may we safely allow to elapse between sprayings without giving the fungus a chance to take hold? From this time to the end of the season my best efforts were devoted to the solution of this question.

During September, October and November, the celery made a rapid

growth and, depending upon various conditions, it required from ten to twenty-five days for the new growth to so over-top the old sprayed leaves as to give the field the appearance of not having been sprayed. The blight first appeared on November 1st, in plot No. 37, which had been sprayed just a month previous. At this time five diseased plants were noted, two adjacent plants being badly affected, while the other three in a different part of the plot showed only a few spotted leaves.

On November 15th a slight scattering of blight was found in plot No. 4, which had been sprayed twice. Between November 1st and December 16th there occurred a rainfall of five and three-quarter inches. This started the late blight in many of the plots but as a whole the field is in good condition. The plants vary somewhat in size, due to the character of the soil, but the average plants are eighteen to twenty inches high. At this date the plots apparently free from blight are: Nos. 1, 2, 4, 7, 8, 9, 14, 16, 17, 21, 23, 24, 25, 26, 27, 28, 29, 31, 33, 34, 35, 38, 44.

Those showing a slight scattering of blight are: Nos. 3, 6, 10, 18, 19, 22, 30, 32, 36, 39, 40, 41.

Those badly affected are: Nos. 5, 11, 12, 13, 15, 20, 37, 42, 43, 45.

The effect of the rain on the spray is shown by the following: No spray is showing on the plants in plots Nos. 1, 3, 5, 7, 8, 9, 11, 12, 13, 14, 15, 20, 21, 22, 23, 24, 26, 27, 30, 31, 33, 36, 37, 38, 46.

A little spray is showing on plots No. 4, 19, 25, 32, 34, 39, 40, 41, 42.

A fair coating of spray is apparent on plots No. 6, 10, 35, 43, 44, 45.

A good coating of spray is still on the leaves on plots No. 2, 16, 17, 18, 28, 29.

While it is difficult to draw any very definite conclusions from the figures, they indicate several very interesting points. With no exception, every plot that shows considerable late blight has been sprayed only once or not at all, and the plots sprayed, with the exception of No. 20, were sprayed only on September 15th. Plot No. 20 was sprayed only on October 1st. The plots showing the most late blight are those that show the least amount of spray on their leaves. The plots that show a good coating of spray are those which were sprayed twice or more and on all of these the spray was put on December 1st.

January 3: The weather during the past week has been very favorable for the growth of the late blight, which has spread pretty generally all over the field and some of the plots are nearly ruined by it. The condition of the plots at this time is as follows:

Those free from blight are: Nos. 2, 4, 17, 28.

Those showing very little blight are: Nos. 1, 3, 9, 10, 14, 16, 18, 19, 21, 23, 24, 25, 27, 29, 32, 33, 34, 35.

The following plots had some blight, though not very serious: Nos. 6, 8, 26, 31, 40.

Those showing considerable blight are: Nos. 7, 11, 13, 30, 36, 37, 39, 41, 42, 43, 44.

Those very badly blighted are: Nos. 5, 12, 15, 20, 22, 38, 45, 46, 47, 48, 49, 50.

In spite of the rain plots No. 2, 17, 19, 27, and 28 still show a good coating of spray, while 29 has a fair coating.

By comparing the observations taken two weeks ago and those of today it will be noticed that of the four plots which are still free from blight, three still have a good coating of spray. The late blight has increased in all but fourteen plots. Thirteen out of eighteen plots that are now but little blighted were healthy up to December 15th, the other five being in about the same condition that they were two weeks ago. Of the five plots that now have some late blight in them (although not enough to be serious) three had none up to December 15th and the remaining had up to that time only a slight scattering. Of the plots that now show considerable blight, two had none December 15th, three had only a very slight scattering, and the remaining ones were in about the same condition. Of the twelve plots that are now nearly ruined by this disease, one had no late blight on December 15th, one had a little, and ten were badly blighted, though they are now in a much worse condition. With one exception, the plots that now have no late blight in them are the ones that have been *sprayed every two weeks,* and all in this group were sprayed for the first time *on or before November 1st.*

The plots that are in the worst condition are the ones that have not been sprayed at all, or have been sprayed for only part of the season. Out of this group of twelve plots, five have received no spray, four have been sprayed only once, two have been sprayed twice, while one has been sprayed three times, commencing with December 1st. All the plots that have been sprayed only once a month have a little late blight in them, and plot No. 39, which was sprayed for the first time on December 1st, is badly blighted. With the exception of plot No. 33, all those that were sprayed every three months are practically ruined by the late blight. All the checks which were not sprayed at all are practically ruined.

CONCLUSIONS AS TO METHODS OF CONTROL.

The writer is fully alive to the danger of drawing premature conclusions from the results of one season's work, still these results have been so emphatic and consistent that it was decided to publish them at this time.

For the prevention of late blight celery plants should be sprayed at least twice while still in the seed bed. A third spraying should be given about a month or six weeks after the plants have been set in the field. The exact time for the third spraying should be governed by the size of the plants, time of year, weather, and the condition of the soil as regards moisture, et cetera. After this they should be sprayed once a month until the rains begin or more often, should the blight appear. From this time on a critical watch should be kept and spray applied as often as necessary to keep the leaf surface well covered, but in no case allow more than two weeks to elapse between sprayings. This is necessary in order to protect the new leaves which continue to push out. This should be continued until harvest.

Application of the Fungicide.—Bordeaux mixture should be applied in the form of a very fine mist and this necessitates a high pressure machine. If a low pressure machine is used and the mixture sprinkled on the plants in the form of drops, it merely runs off on the ground and is wasted. While the plants are small, going over the field once is sufficient for each application. When the plants have reached a height of fifteen inches it will be necessary to go over the field twice for each application. To do this to best advantage, it is well to go over the field in the ordinary way, then go back to the first row sprayed and proceed in the opposite direction from that traveled before. This plan not only tends to wet both sides of the leaves, but it allows time for the first spray to dry. If the machine returns at once on the same row, the drops of liquid will coalesce and run off the plants. Many persons are puzzled to know just how much spray to put on. They should realize that, if the tiny particles of spray are not thick enough on the leaf the fungus spores may gain entrance in between them, while if they are put on too thick they will coalesce into drops and run off the plant. Therefore, the skillful sprayer will attempt to strike a medium and cover the foliage as thoroughly as he can with the mist. While the plants are yet small thirty to forty gallons of Bordeaux will be required to the acre, but when the crop is fifteen inches high it will require at least one hundred gallons per acre to cover the foliage in the way described above.

The Preparation of Bordeaux Mixture.—On preparing Bordeaux mixture, the first step is to make up a quantity of stock solution of the copper sulphate and lime. It is very important that this be done carefully. The first step is to nearly fill two fifty-gallon barrels with water. One is to be used for the blue stone and one for the lime. Next, weigh out fifty pounds of blue stone in a sack and suspend it near the surface of the water in one of the barrels. So placed, it will

dissolve much faster than if placed in the bottom. Next, weigh out fifty pounds of stone lime and after carefully slaking it by adding water, a little at a time, pour into the other barrel. It is very essential that the lime be well slaked and this is best done by putting fifteen or twenty pounds at a time into a tub and adding water little by little until it becomes a thick, smooth paste.

It is also very important that the stock solutions should be diluted before they are mixed. According to the above directions, one gallon of the stock solutions will contain one pound of blue stone or lime. Two other barrels should now be filled with nearly enough water to make a tank full of mixture, and the required amount of stock solution added to each. Thus, the two solutions are diluted separately

Fig. 9.—Mixing Bordeaux.

Fig. 10.—Mixing Bordeaux.

Fig. 11.—Mixing Bordeaux.

and are ready to be mixed. The mixing should be done while the two solutions are running into the tank simultaneously. One very satisfactory way of mixing is by means of a pump shown in Figure 9. This has two pieces of hose, one drawing the dilute lime and the other the dilute blue stone, while a single pipe delivers the mixture to the tank. The object of this care is to prepare the Bordeaux in such a manner that it will remain in suspension in the water for as long a time as possible. Another very good way of running the solutions into the tank is shown in Figs. 10 and 11. All of these platforms perform the work well and there is very little choice between them. The platform is usually built over the well or ditch from which the water is taken and the floor is six inches to one foot from the top of the spray tank. It is large enough to hold six barrels; nine feet square being a convenient size. The barrels are placed in a row, the center two being used for diluting. Stopcocks near the bottom of these are attached to hose which convey the contents to a trough which delivers the mixture into the spray tank through a thirty-mesh sieve. Some water is usually added later to fill the tank.

In order to illustrate the importance of properly mixing the Bordeaux, the writer contrived the experiments shown in Figs. 12, 13, 14, and 15. Fig. 12 was taken after the Bordeaux was mixed and undisturbed for two hours, fig. 13 shows the same mixtures after six hours, and fig. 14 after an elapse of seventy-two hours. In figs. 12, 13, and 14, bottle No. 1 contains Bordeaux in which the blue stone and lime were diluted and poured into the bottle simultaneously. Bottle No. 2 contains Bordeaux prepared by pouring the blue stone and lime solutions together concentrated and then diluting to the same strength as No. 1. No. 3 was mixed in exactly the same manner as No. 1 except that the solutions were not diluted before being mixed.

While the mixture made by not diluting the stock solutions before mixing is far better than the one which was mixed concentrated and then diluted to the required strength, it is not as good as the mixture made by first diluting the stock solutions. The longer the Bordeaux is allowed to stand, the greater the difference until after seventy-two hours; see fig. 14.

To still further show the difference due to different methods of mixing, the writer prepared an exhibit shown in fig. 15, bottles 4, 5, and 6. Bottle No. 5 contains properly mixed Bordeaux; No. 6 has had the lime poured into the water, then a concentrated solution of blue stone. Bottle No. 4 has had the blue stone solution poured into the water and then the concentrated solution of lime. Fig. No. 15 was taken after the mixture had stood for three hours undisturbed. This

Fig. 12.—See page 106.

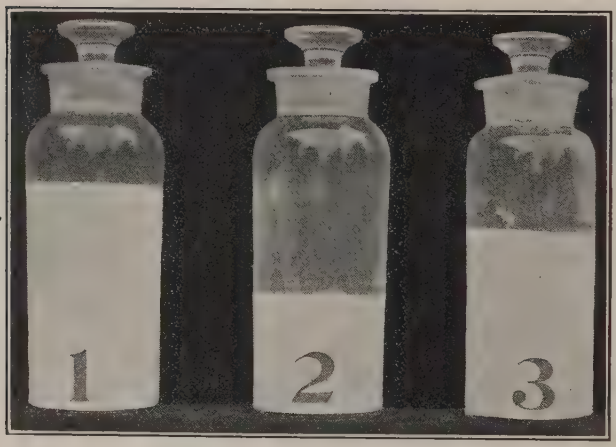

Fig. 13.—See page 106.

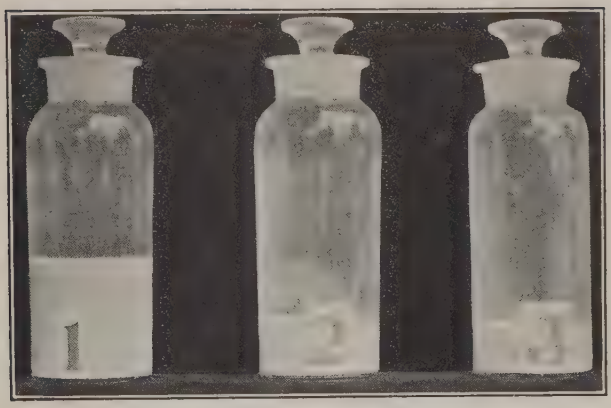

Fig. 14.—See page 106.

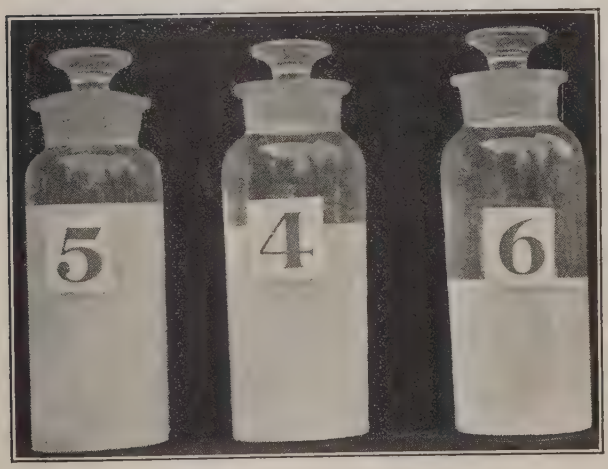

Fig. 15.—See page 106.

illustrates very conclusively that Bordeaux must be prepared by first diluting the stock solutions before they are mixed and the mixing should be done while they are being poured into the tank.

Another important question which has not been fully worked out is: Just what strength of Bordeaux should be used for celery late blight? The strength used on our experiment plots and in the main celery fields proved very satisfactory and is recommended accordingly.

Strength of Bordeaux recommended:

Blue stone, 5 lbs.
Stone lime, 6 lbs.
Water, 50 gallons.

Fig. 16.—Small capacity spraying machine; power derived from gear wheels.

Spraying Machinery.—There are two different types of spraying machines used in Orange County. The oldest and probably the most common in use is shown in Fig. 16. The spray tank has a capacity of 150 gallons and is supported on a two-wheeled vehicle drawn by two horses. The pump which sprays the material onto the plants is worked by a chain which runs on a gear fastened to one of the wheels. It is possible to get a pressure of one hundred pounds or more. This machine sprays four rows at a time and it is possible to spray ten acres a day going over the plants once. As will be seen by the figure, two nozzles are used for each row, so as to cover the stalks as well as the tops with the spray mixture. While this machine does fairly

thorough work, it has several disadvantages. The main difficulty is to maintain a steady pressure, as the pressure is wholly dependent upon the rate the machine moves. When the machine is turning at the ends of the rows the pressure at once drops and as it cannot be brought up again until the machine is under way, several plants will be left unsprayed. The pull on the horses is very heavy, especially when the fields are muddy.

By far the most desirable type of spraying machine is shown in Fig. 17. This machine gives great satisfaction, and the use of a machine of this type is strongly advocated. The pressure is maintained by the gasoline engine, which is situated in the rear of the tank. A

Fig. 17.—Large capacity spraying machine; power derived from gasolene engine.

spraying machine as large as this one is not always economical, especially for the growers who have only a few acres of celery. But fortunately there are several small engines on the market which are suitable for this class of growers. The strong point in favor of this type of machine lies in its ability to maintain a steady high pressure, whether the sprayer is moving or not. The churn in the tank which keeps the mixture well agitated is also run by the engine. This machine, which is shown in Fig. 17 sprays six rows of celery at a time and will go over twenty acres a day, spraying the plants once. The cost of these engines varies from fifty to four hundred dollars, depending upon their size.

It is very essential in order to apply the spray regularly and thoroughly that the spraying machine should be kept in good condition.

The nozzles will soon be in bad shape if not cared for, due to the action of the blue stone, and in a short time the holes through which the spray passes will be so large that the contents of the tank will be poured instead of sprayed onto the plants. To avoid this condition, the nozzle should be washed in clean water at the end of each day that the spray is used, or better still, water should be run through all the pipes.

The Cost of Spraying and the Profits Resulting Therefrom.—If the 5-6-50 Bordeaux formula is used and calculating the blue stone at 5¼¢ per pound and the lime at 1¢ per pound, the material necessary to make up 50 gallons of the Bordeaux will cost 32¢. The total cost of the materials used per acre for the entire season will vary from $2.00 to $5.28.

In order to show the profits from spraying, the crop grown in the fall of 1907 and spring of 1908 will be referred to. As has already been mentioned, this was the season in which the blight was so disastrous. Six thousand acres were planted to celery in Orange County this year, and the loss from this disease is estimated at $550,000.00[6] In fact, practically the bulk of the crop was ruined. With the exception of 80 acres of celery grown on the Golden West Ranch no spraying was done. The celery in this field was sprayed thoroughly during the entire season and very few plants were lost by the blight. *The gross returns from the celery grown on this 80-acre tract was $27,000.*

While it is quite difficult to estimate the actual losses from this disease during the last two seasons, the following estimates were made by one of the directors of the Orange County Celery Growers' Association:

"The loss due to the late blight in 1908 was approximately $25,000 and in 1909 the total loss was $10,000. In both seasons much of the loss was caused by growers who would not spray thoroughly nor mix the spray properly."

The season of 1909 was much more favorable for the growth of the blight than the previous year, although not nearly the amount of loss occurred owing to the fact that more of the growers were spraying persistently and thoroughly.

The actual cost of buying the materials and applying them is practically nothing in comparison to the results derived. The actual cost of spraying is dependent on the number of times the spray is applied. This in turn is dependent upon several conditions, namely: the time of harvesting, weather conditions and the thoroughness of the work.

[6] See Cal. Exp. Sta. Bull. No. 203, page 41.

Celery that is shipped in November will have been sprayed possibly only four or five times, while celery that is not harvested until March will probably have been sprayed ten or eleven times. Not only the time at which the crop is harvested will indicate the number of sprayings necessary, but the climate and especially moisture conditions. It has been indisputable so far that the earliness of the rains and fogs determine the time of prevalence of the blight and a large amount of rain or fog is certain to be followed by a rapid increase of the disease.

And lastly I would emphasize the fact that skillful and effective spraying, looking toward the elimination of the *sources of infection* will greatly reduce the cost of protecting the crop. This is especially true where thorough spraying is the rule in all adjacent celery fields.

OTHER FUNGUS DISEASES AND INJURIOUS INSECTS.

Aside from the Late, or Winter Blight, there are several other troubles which result in some damage to the celery crop. Some of these will be briefly discussed.

Early Blight (*Cercospora apii* Fr.).—This disease occurs more or less generally throughout the State, yet it has never been the cause of serious loss. It appears on the plants early in the season, the lower outside leaves becoming infected first. It soon spreads to the inner leaves, but is never found on the stalks. The threads of this fungus work themselves into the tissues and cause brown spots generally in the center of the leaves. This disease often affects the plants while in the seed bed. Hot, moist weather is most favorable to its growth.

If the disease becomes serious, spray with Bordeaux mixture as described for Late Blight. Thorough cultivation and, in fact, any operation that will favor quick growing, healthy plants is strongly recommended.

Stem Rot (*Sclerotinia*).—This disease is found on the plants only late in the season after the rains have started. Although this is not uncommon, it does very little damage. It is more prevalent in places that are poorly drained and has been noticed in some instances where a large weed rotted next to celery plant.

Root Rot (*Fusarium*).—This disease occurs only in extremely wet places; generally more abundant after the rains have started. Good drainage and cultivation will control it. No large losses have been reported due to this fungus.

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1896. Report of the Viticultural Work during the seasons 1887-93, with data regarding the Vintages of 1894-95.

1897. Resistant Vines, their Selection, Adaptation, and Grafting. Appendix to Viticultural Report for 1896.

1902. Report of the Agricultural Experiment Station for 1898-1901.

1903. Report of the Agricultural Experiment Station for 1901-03.

1904. Twenty-second Report of the Agricultural Experiment Station for 1903-04.

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202. Commercial Fertilizers. (December, 1908.)

203. Report of the Plant Pathologist to July 1, 1909.

204. The Dairy Cow's Record and the Stable.

205. Commercial Fertilizers. (December, 1909.)

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35. Southern California Pathological Laboratory and Citrus Experiment Station.
36. Analyses of Fertilizers for Consumers.
37. Announcement of Farmers' Short Courses for 1908.
39. Instruction in Practical Agriculture at the University Farm.
46. Suggestions for Garden Work in California Schools.
47. Agriculture in the High Schools.
48. Butter Scoring Contest, 1909.
49. Insecticides.
50. Fumigation Scheduling.
51. University Farm School.
52. Information for Students Concerning the College of Agriculture.
53. Announcement of Farmers' Short Courses for 1910.
54. Some Creamery Problems and Tests.
55. Farmers' Institutes and University Extension in Agriculture.
57. Announcement of Farmers' Short Courses in Animal Industry and Veterinary Science.